ESSEX

FINAL REPORT

SPACE TELESCOPE
DESIGN DEVELOPMENT MOCKUP

CONTRACT NAS8-33272

SEPTEMBER 13, 1983

ESSEX REPORT NO. H-83-06

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SPACE TELESCOPE FINAL REPORT

Contract No. NAS8-33272

Prepared For:

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FOREWORD

This report describes the tasks performed and end products developed by Essex for NASA's Marshall Space Flight Center under contract NAS8-33272. During the 4½ year contract, Essex designed and fabricated Space Telescope mockups, servicing tools, spares carrier mockups and a flight support system. Essex also supported the Neutral Buoyancy Simulator tests by installing the test hardware, providing divers during the tests, preparing test plans and reports and modifying the test hardware as needed.

This report describes the contract tasks and end products and presents some observations made during the contract performance.

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1.0 INTRODUCTION

1.1 PURPOSE OF CONTRACT

Since November 28, 1978, Essex Corporation has been under contract to NASA's George C. Marshall Space Flight Center for the development of a Space Telescope design development mockup for use in the MSFC Neutral Buoyancy Simulator (NBS). Since the beginning of the contract, numerous underwater tests have been performed with pressure-suited engineers and astronauts to evaluate the crew tasks associated with both planned instrument changeouts and unscheduled repairs. These tests have resulted in flight hardware modifications and better definition of the crew procedures. Throughout the contract, Essex' tasks have been consistent:

- Review flight hardware concepts and drawings
- Prepare mockup drawings
- Fabricate mockup hardware
- Support test operations.

Although the task titles have remained the same, the hardware produced during the contract has varied considerably. The major hardware items produced include the following:

- Aft shroud - frame, skin, floor
- Focal Plane Assembly - structure, guiderails, preload devices, latches, equipment shelf with star trackers (3)
- Scientific Instruments - axial and radial
- Support Systems Module (SSM) Equipment Section - frame, skin, doors
- Optical Telescope Assembly (OTA) Equipment Section
- Orbital Replacement Units for SSM & OTA equipment sections
- Light Shield - 18 ft.
- Solar Array
- Diode Box
- ORU Spares Carriers
- Crew Aids - handrails, foot restraints and sockets.

In addition to providing the above hardware, Essex also provided support for the NBS tests in the form of test conductors, test observers, hardware setup, hardware repairs and modifications during the test, and test reports. Simulation test plans provided by Essex prior to the test runs include the following:

- NBS 33 - Rate Sensor Unit/Star Tracker Access Evaluation
- NBS 34 - Axial ST Removal/Replacement
- NBS 35A - Evaluation of the Solar Array as in ORU
- NBS 35B - Evaluation of the Solar Array Mechanisms.

Several contract modifications resulted in the performance of Space Telescope mockup related tasks but actually had little to do with development of the Space Telescope mockup hardware. These tasks include:

- Mod 2 - Development of an Advanced X-Ray Astrophysics Facility Orbital Maintenance Plan
- Mod 6 - Development of Three Spacelab-2 Pallets and Approximately 30 Experiment Mockups
- Mod 7 - Development of Approximately 40 Spacelab-1 Experiment Mockups and European Bridge Structure.

The contract tasks, end products, results and conclusions are described in the following sections.

1.2 CONTRACT HISTORY

The basic contract has been modified 11 times since its beginning. These modifications have been to provide more mockup hardware, revise existing mockups as the flight design changed, provide maintenance mission support equipment and provide related support to the Spacelab and AXAF projects based on mockup fabrication techniques and on-orbit servicing experience gained from the Space Telescope experience.

A flow chart of contract modifications is presented as Figure 1 and shows the major end product for each modification.

2.0 TECHNICAL APPROACH

During the basic contract and modifications 1, 3, 4, 5, 8, 9, 10, and 11, Essex performed the same generic tasks but for different parts of the Space Telescope mockup. These tasks were:

Task A - Review Space Telescope Drawings
Task B - Prepare Mockup Drawings
Task C - Fabricate Mockups.

Although the mockup hardware produced during the performance of the tasks varied considerably, the type of activities required to turn flight drawings or concept sketches into mockup hardware remained fairly constant. These tasks are described below.

2.1 TASK A - REVIEW SPACE TELESCOPE DRAWINGS

During this task, Essex reviewed the available Space Telescope drawings and concept sketches to serve as a basis for the mockup design effort. Essex also identified any dimensions, equipment configurations or interfaces not defined by the available drawings that were needed to perform mockup design. After examination of these drawings and sketches, Essex determined the functional requirements of each mockup component and identified the fidelity requirements. During drawing review and subsequent design, fabrication and testing activities, Essex had frequent contact with Lockheed, Perkin-Elmer, and British Aerospace Personnel to ensure that the latest hardware designs were duplicated on the mockup hardware.

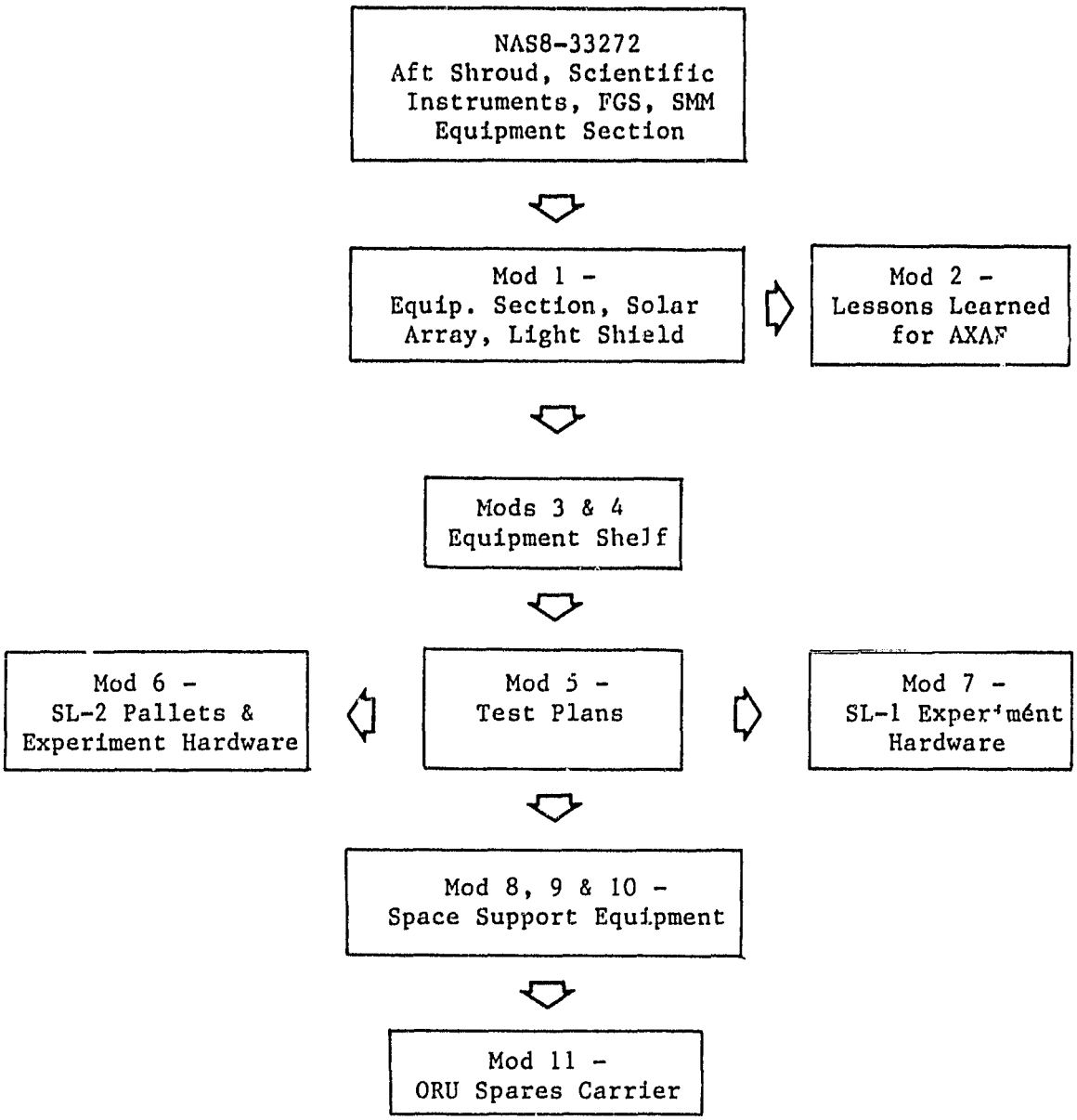

Figure 1: Space Telescope Contract History

2.2 TASK B - PREPARE MOCKUP DRAWINGS

Essex then prepared detailed sketches of the Space Telescope mockup hardware showing key dimensions and illustrating the configuration and fidelity of all mockup components. These sketches were then provided to the COR for review and approval before preparation of the detailed engineering drawings.

After approval of the configuration sketches, Essex developed the mockup drawings. All mockup drawings specified materials and finishes compatible with the neutral buoyancy environment and specified edge and corner requirements to prevent injury to pressure suited crewmen and support divers.

2.3 TASK C - FABRICATE MOCKUPS

After COR approval, Essex released the drawings to the Essex shop. During mockup assembly all mockup components were available to NASA personnel for inspection. As the mockups were completed, they were examined by Essex designers for compatibility with the drawing requirements including materials and finishes, dimensions, tolerances, and equipment interface provisions.

After approval of the hardware in the Essex shop by the COR, the mockups were delivered to the MSFC NBS through Building 4471, Shipping and Receiving, along with appropriate shipping labels and copies of Form DD 250.

3.0 END ITEM DESCRIPTION

The contract end items are listed in Table 1 and include all hardware and reports prepared for Space Telescope, AXAF and Spacelab. These items are described in the following paragraphs.

3.1 SPACE TELESCOPE

The Space Telescope-relatated deliverables include the neutral buoyancy mockup, space support equipment and test plans.

3.1.1 Space Telescope Mockup

Figures 2 and 3 show the as-built mockup configuration and the major mockup components. The mockup was fabricated in sections and assembled in the NBS by Essex and MSFC divers. All components weight less than the 1800 lb overhead crane limit and are less than 12 ft. tall to pass over the tank walkway at the highest crane hook height.

The major mockup sections are the aft shroud (2 sections), focal plane assembly, Space Support Module (SSM) equipment section, optical telescope assembly (OTA) equipment section, and light shield (3 sections). Other equipment such as the solar array, magnetic torques and orbital replacement units (ORUs) were attached to these major sections before or after assembly of the mockup in the NBS.

Table 1: Summary Of Contract Modifications
And Specific End Items

TECHNICAL ACTIVITY	CONTRACT MODIFICATION	SPECIFIC END ITEM
Space Telescope Mockups	Basic Contract	Aft Shroud and Focal Place Assembly Alignment Devices, Guiderails Preload Devices & Latches Scientific Instruments (3) Fine Guidance Sensor Handrails Foot Restraint Sockets SMM Equipment Section ORUs for SMM Equipment Shelf, Star Trackers and RSUs (2 configurations)
	Mod 1	OTA Equipment Section Light Shield - 18 ft. Solar Array Diode Box
	Mod 3, 4	New Equipment Shelf & 3 Star Trackers and RSUs
	Mod 5	NBS Test Plans
	Mod 8, 9	ORS Transfer Device ORU Spares Carrier Spacelab Pallet Foot Restraints SSM Handrails & Cables Flight Support System Faint Object Camera Axial SI Rails (2 sets) Bay 10 ORUs Keel & Trunnion Fittings OTA Equipment Section, one High Fidelity Bay Updated Equipment Shelf & Star Trackers (3) Light Shield Rings, Handrails Magnetic Torquers (4) RMS Grapple Fixture Upgraded Fine Guidance Sensors (2) Light Shield Flotation Upgraded Solar Array New Flight Configuration Hi Fidelity Diode Box
	Mod 10, 11	ORU Spares Carrier Modifications Crew Aids Flotation/Support Structures
Advanced X-Ray Astrophysics Facility	Mod 2	AXAF Orbital Maintenance Plan - Preliminary
Spacelab - 2	Mod 6	Three Spacelab Pallets 30 Experiment Mockups
Spacelab - 1	Mod 7	40 Experiment Mockups European Bridge Structure

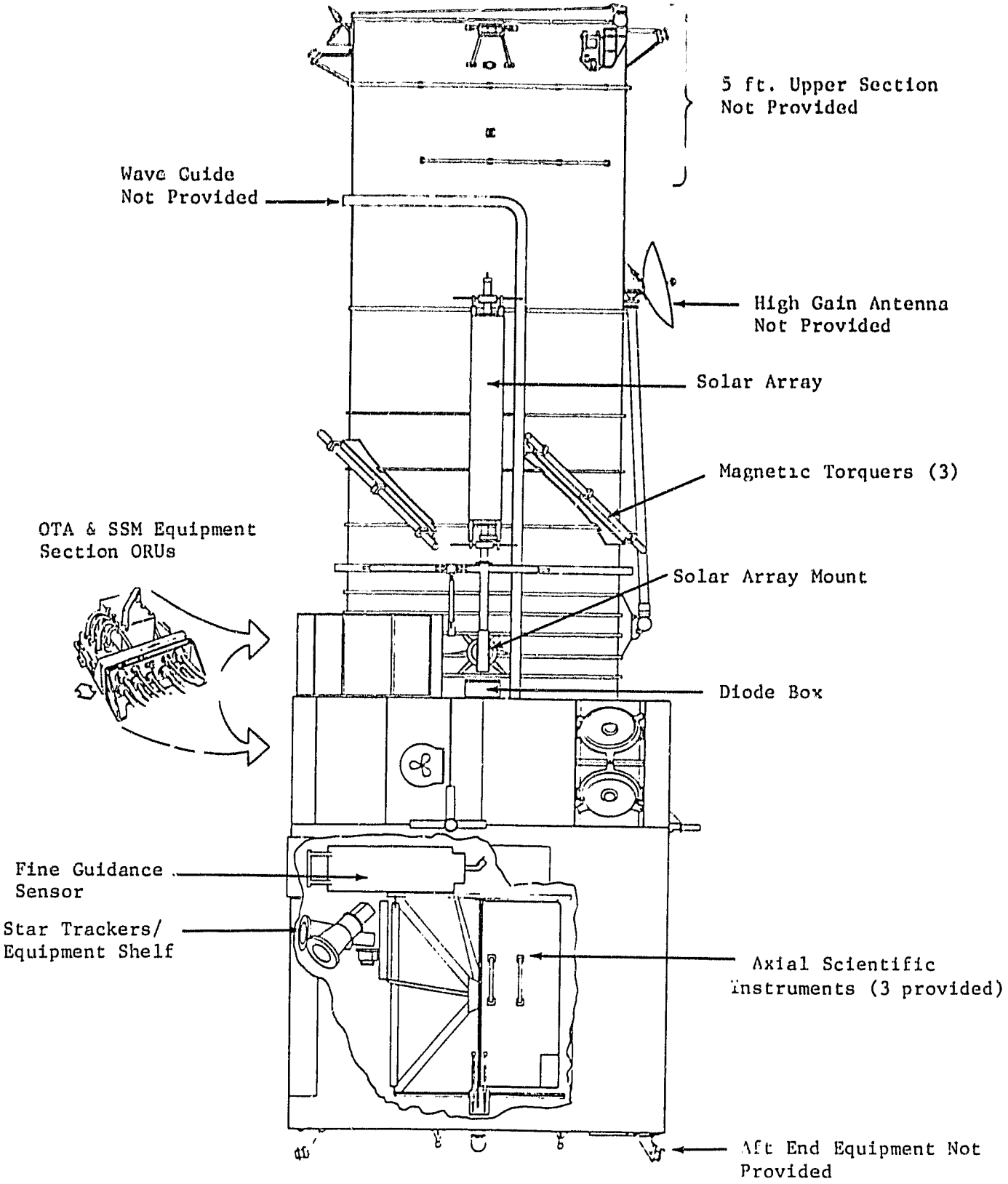

Figure 2: ST Mockup Configuration

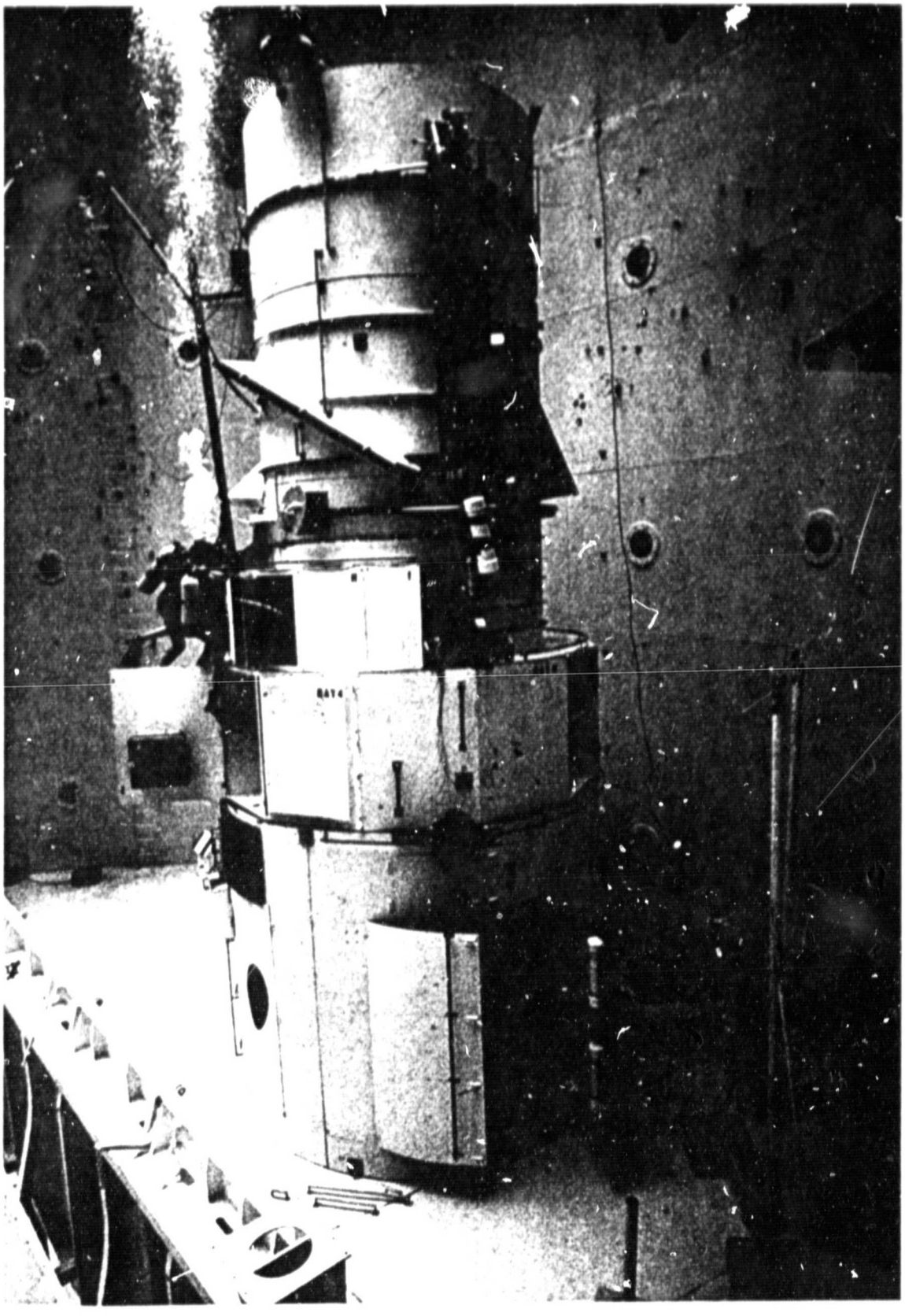

Figure 3: Space Telescope NBS Mockup

The aft shroud focal plane assembly and attached ORU latches and insertion guiderails were built to flight hardware accuracy requirements and were used for one-G insertion/removal tests.

The major mockup sections and attachment hardware are shown in Figures 4 through 12.

In addition to the Space Telescope mockup, Essex also provided a Flight Support System (FSS) cradle and berthing platform (Figures 13 and 14) for positioning the telescope during servicing. This FSS was Cradle A' developed for the Multimission Modular Spacecraft servicing and return operations.

Essex also developed an ORU spares carrier which consists of a Spacelab pallet, ORU stowage racks, an environmental enclosure, an overhead rail system and an ORU transfer device. Figures 15, 16 and 17 show the spares carrier and its major components.

3.1.2 Space Support Equipment

Throughout the contract Essex developed tools for ORU changeout and manual override of EVA mechanisms. Several of the ratchet wrenches are shown in Figure 18. The last EVA ratchet wrench developed for ST servicing is shown in Figure 19. This wrench has a tether ring for attachment to the EMU suit tether, a palm wheel for use with the glove, a large cross-section handle for easier gripping, and a ball detent with a push button release for securing the socket or extension to the 3/8 in. drive.

Since this wrench was fabricated, Essex designed and fabricated two flight wrenches and a trainer for STS-5. Essex also modified the ball detent locking feature for a wrench provided to JSC to produce a more positive locking feature. Both tasks resulted in design and material changes that should be incorporated into the flight ST servicing wrenches.

Essex also provided EVA Foot restraints and attachment sockets for the servicing workstation.

3.1.3 Test Plans

Several test plans were prepared as part of the contract modification No. 5. These plans include:

- NB-33 Rate Sensor Unit/Star Tracker Access Reevaluation
- NB-35A Evaluation of a Solar Array as an ORU
- NB-35B Evaluation of Solar Array Mechanisms
- Determine Space Telescope Crew Restraint Locations
- Evaluate SI Latch/Preload Crew Tasks and Restraint Locatons
- Verify Radial SI and Wide Field Planetary Camera Insertion/Removal Forces and Clearances.

During each NBS test, Essex provided test support in the form of test conductors, utility divers and real-time hardware modifications.

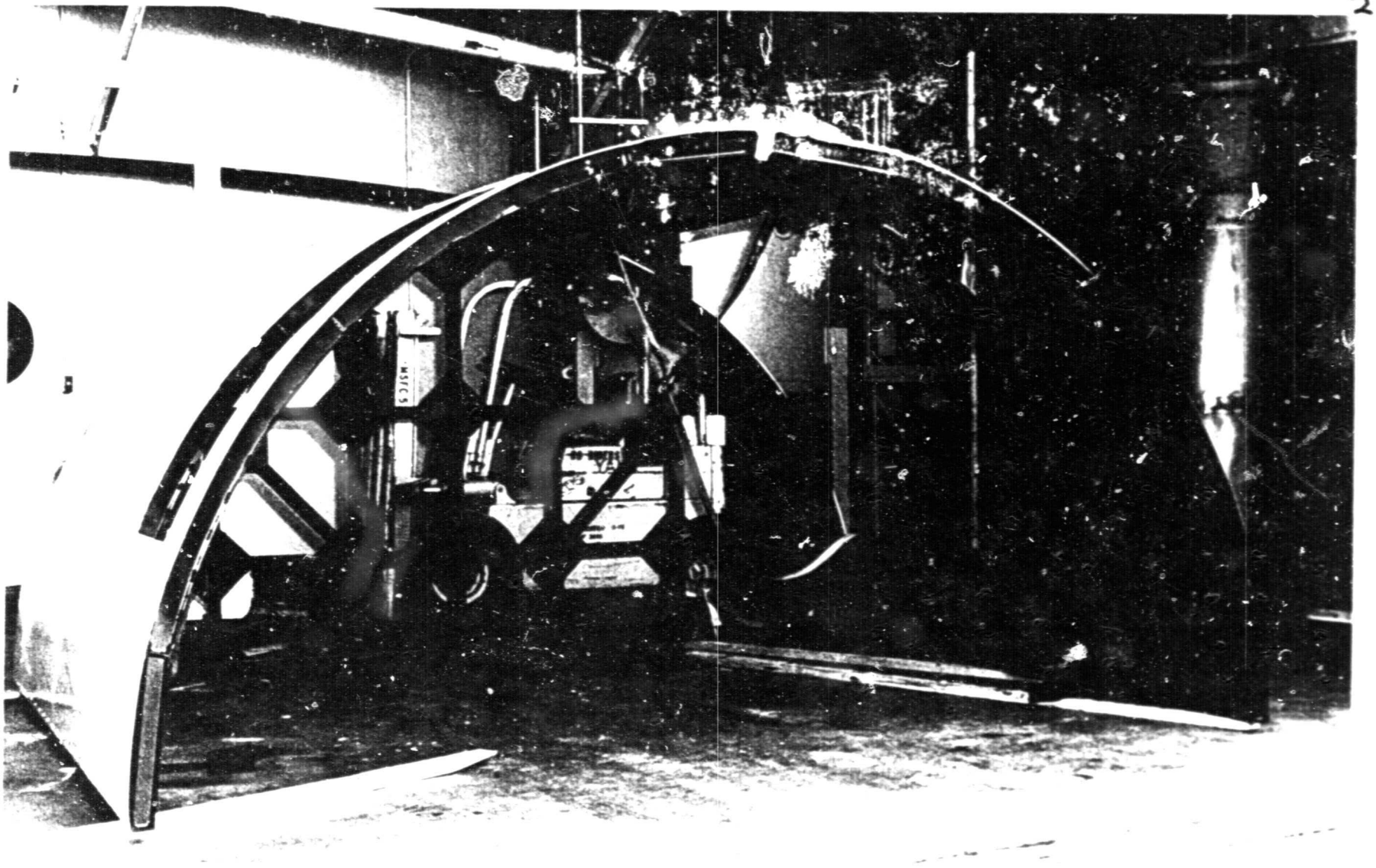

Figure 4: Aft Shroud Half-Section

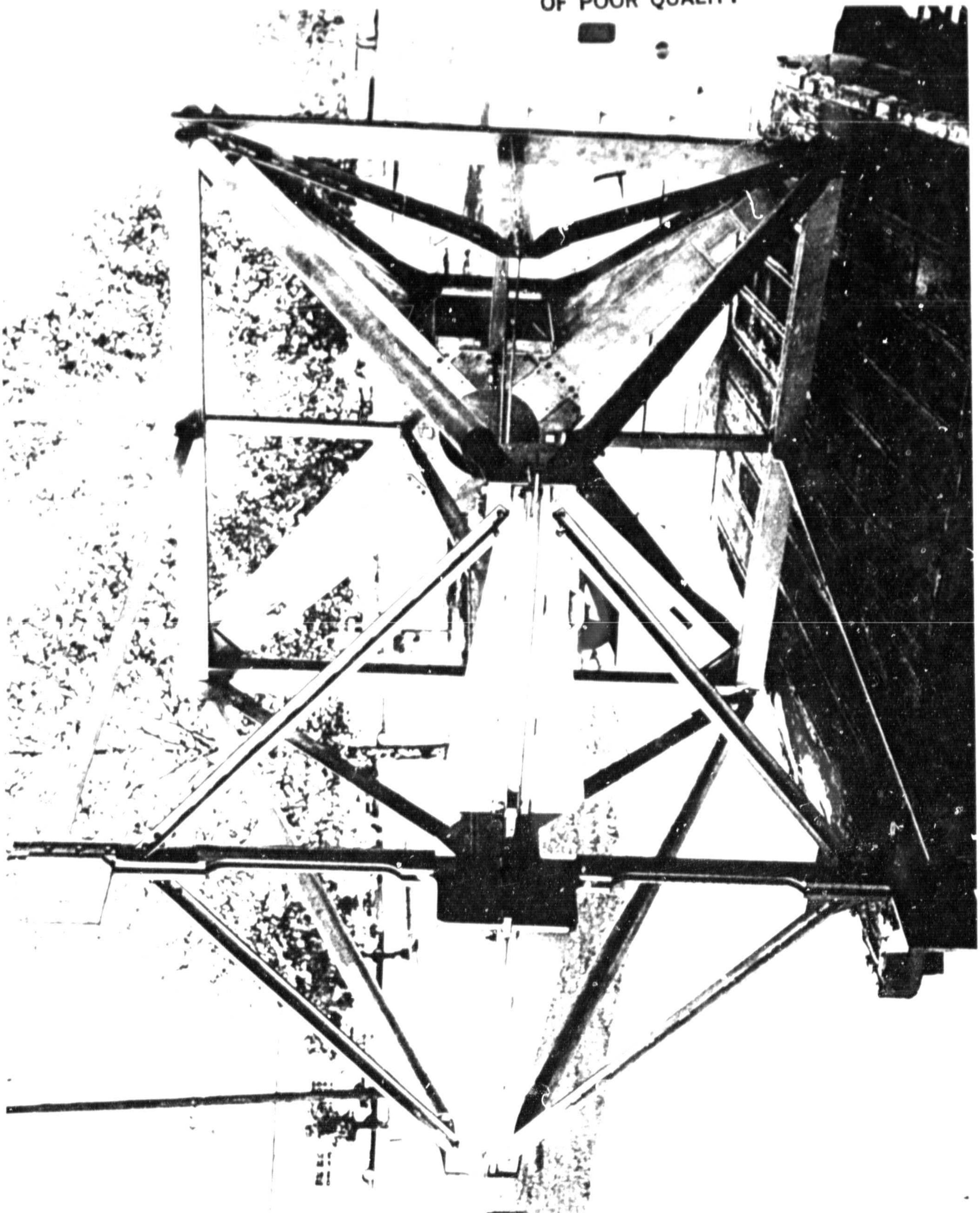

Figure 5: Focal Plane Assembly

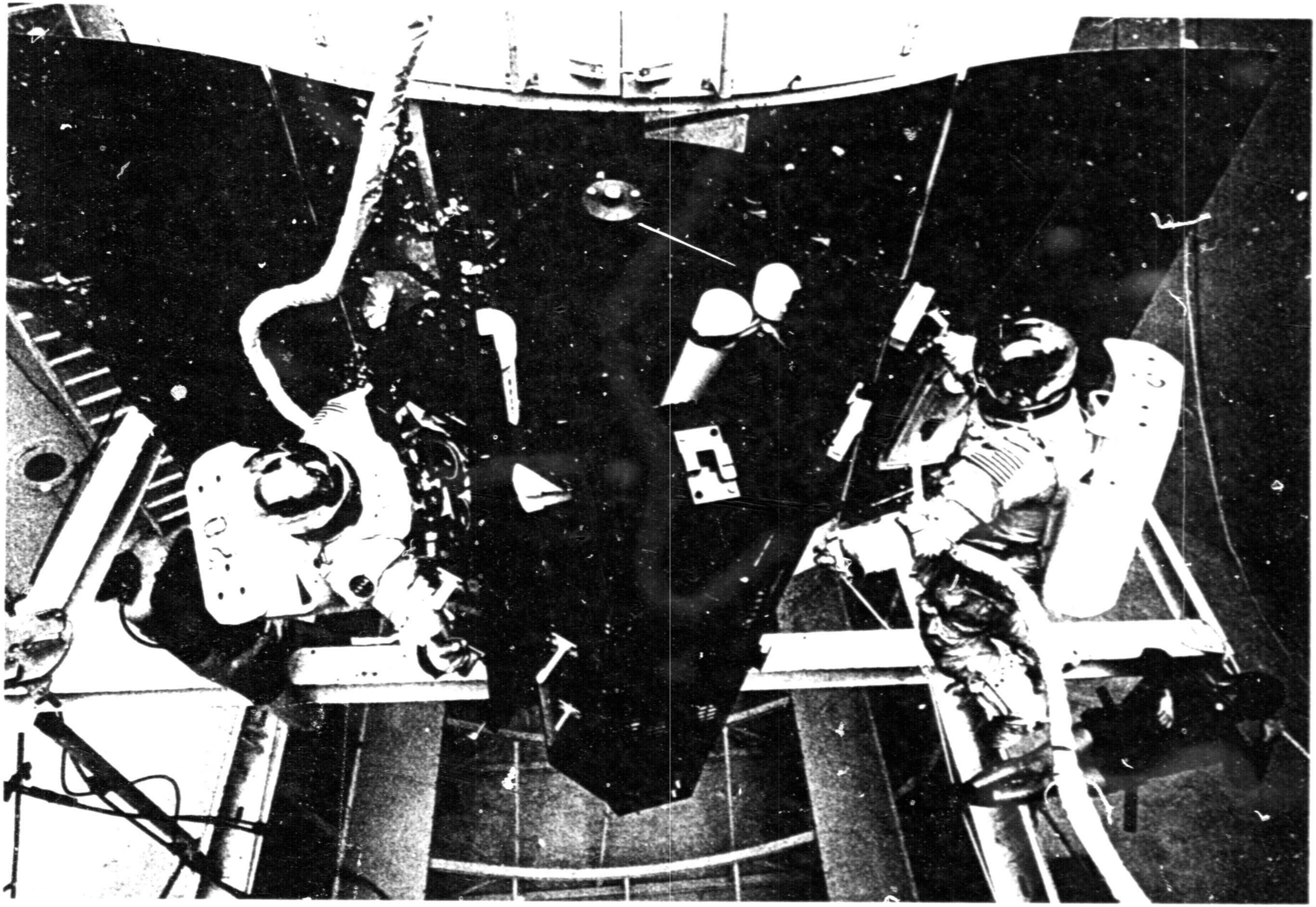

Figure 6: Axial Scientific Instrument Changeout

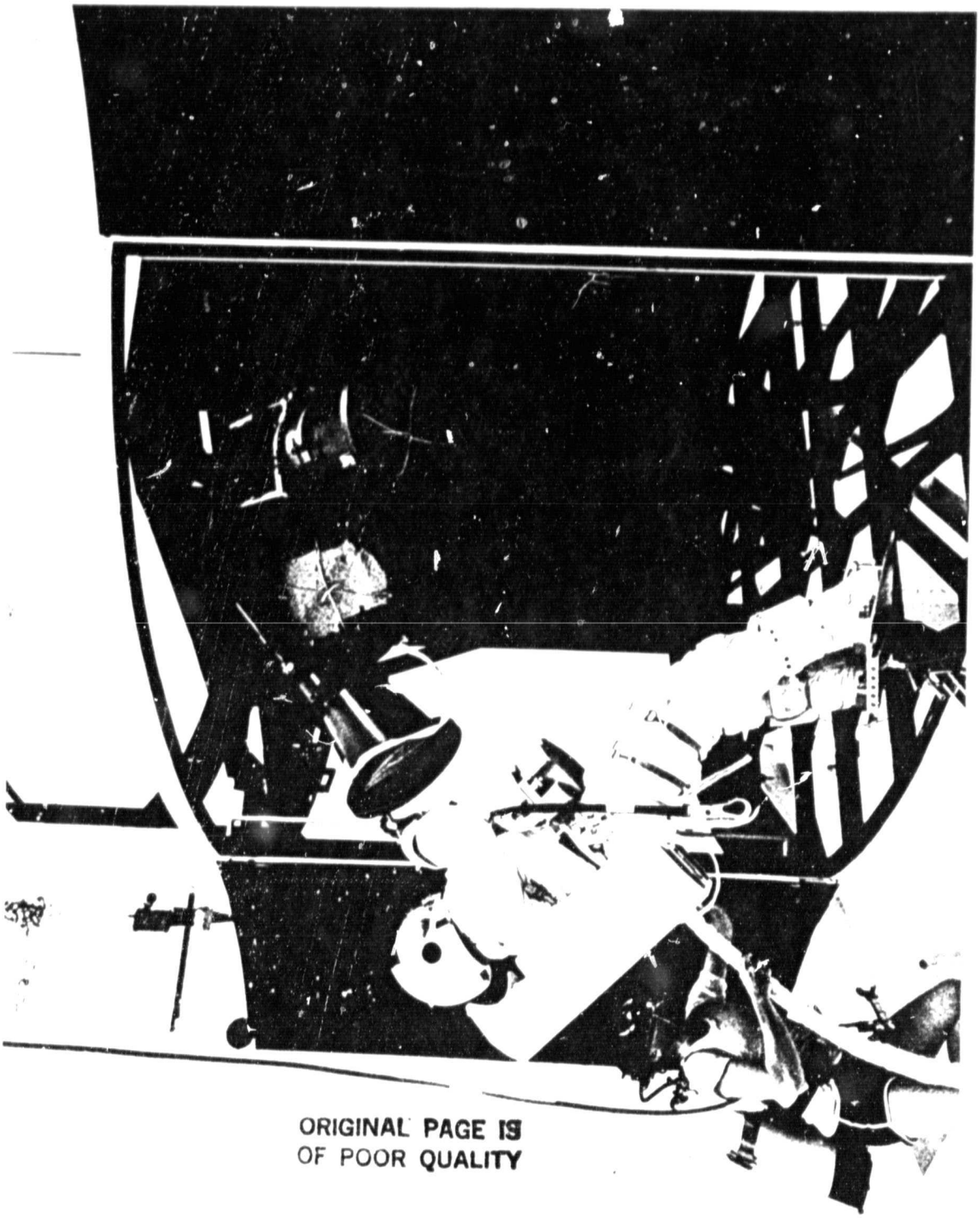

Figure 7: Star Tracker Changeout

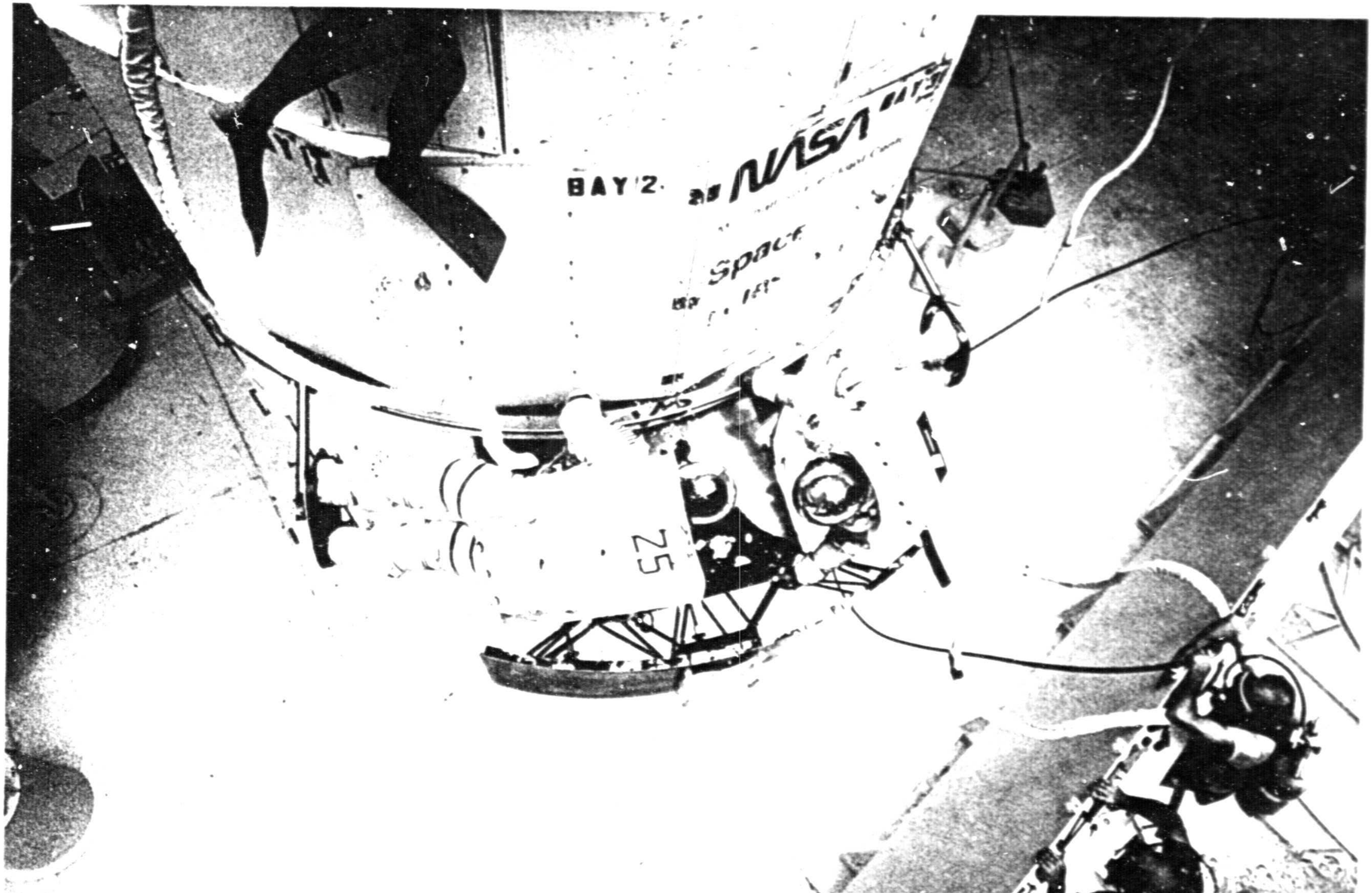

Figure 8: Wide Field Planetary Camera Changeout

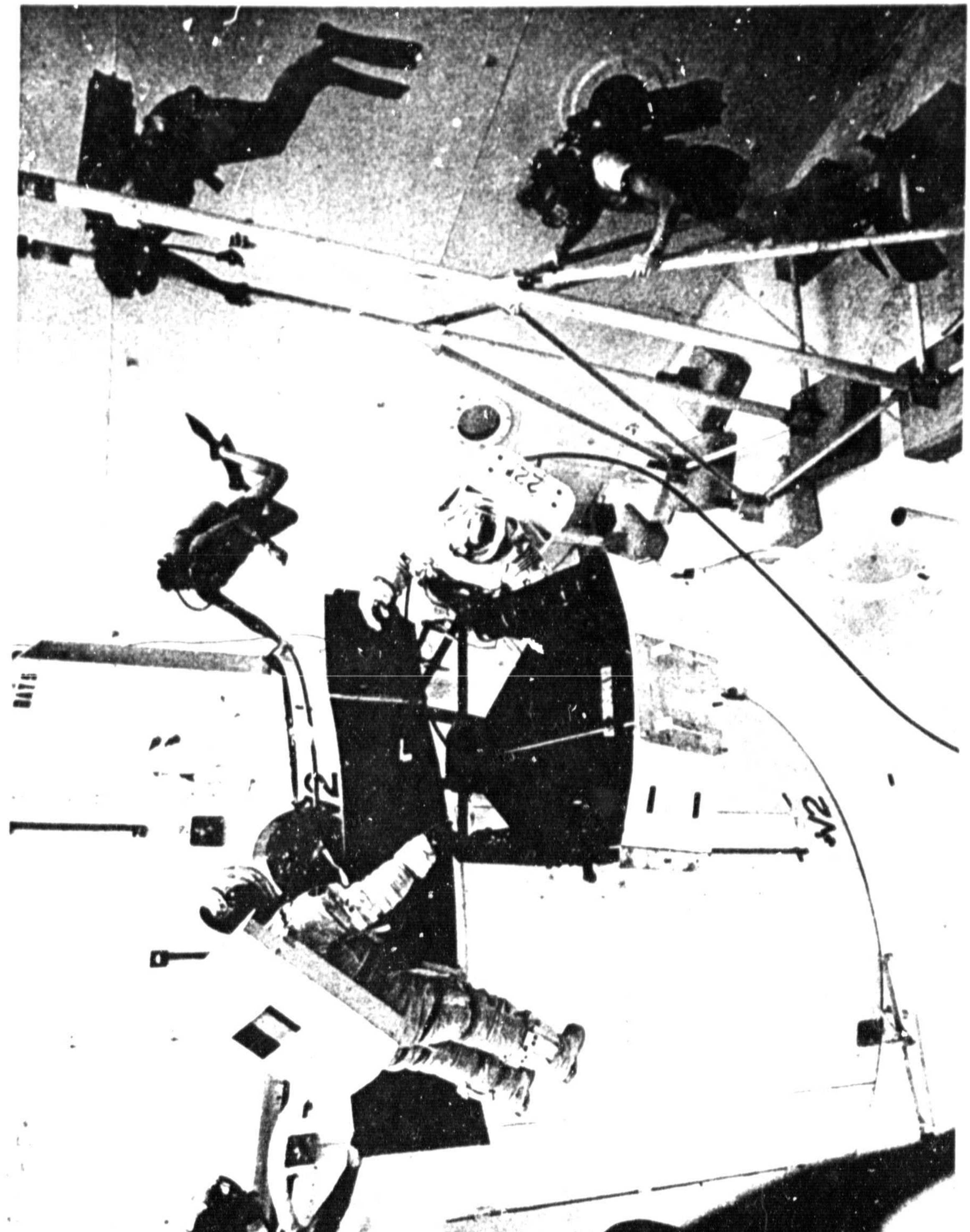

Figure 9: Fine Guidance Sensor Changeout

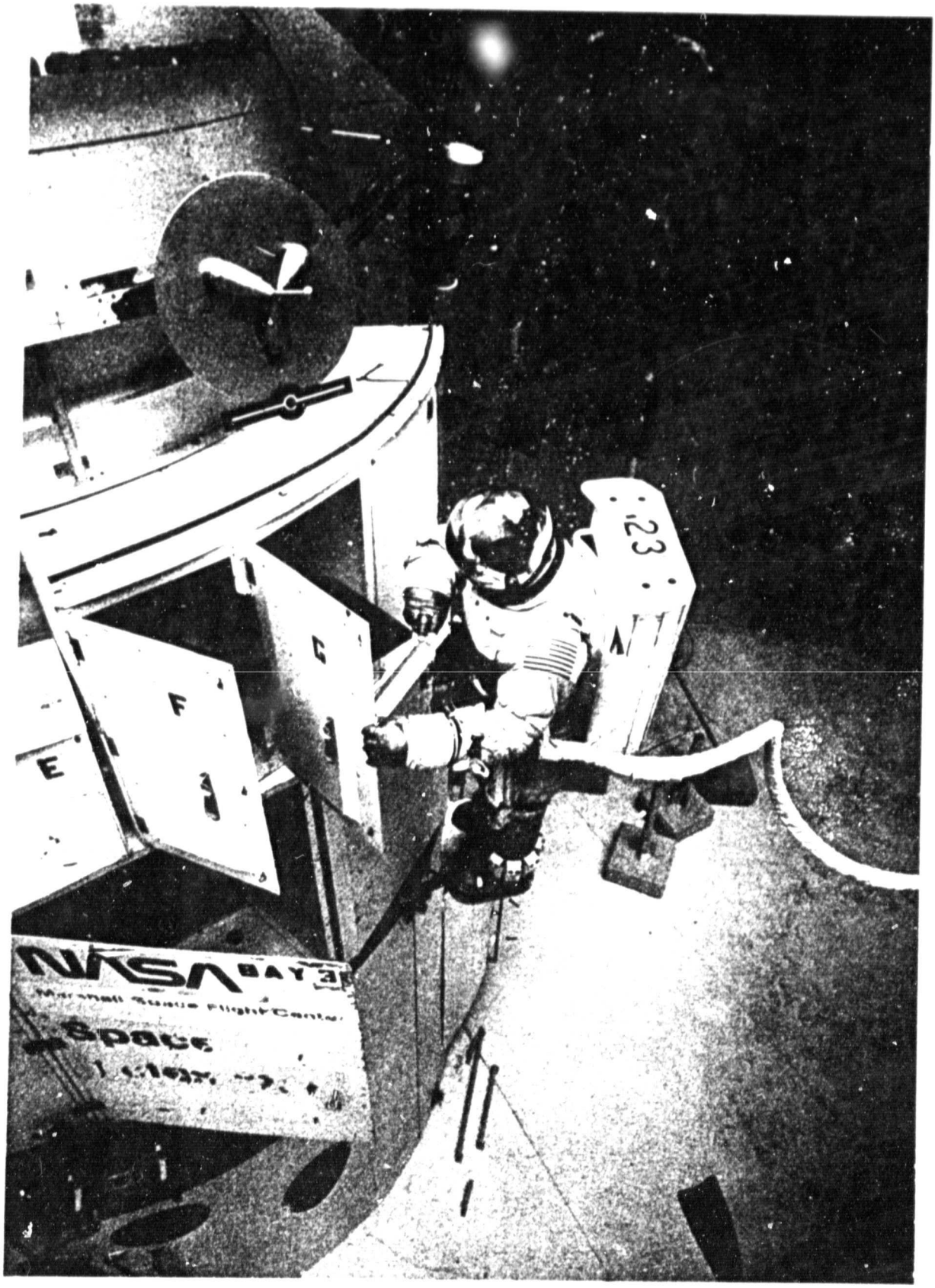

Figure 10: Equipment Section ORU Changeout

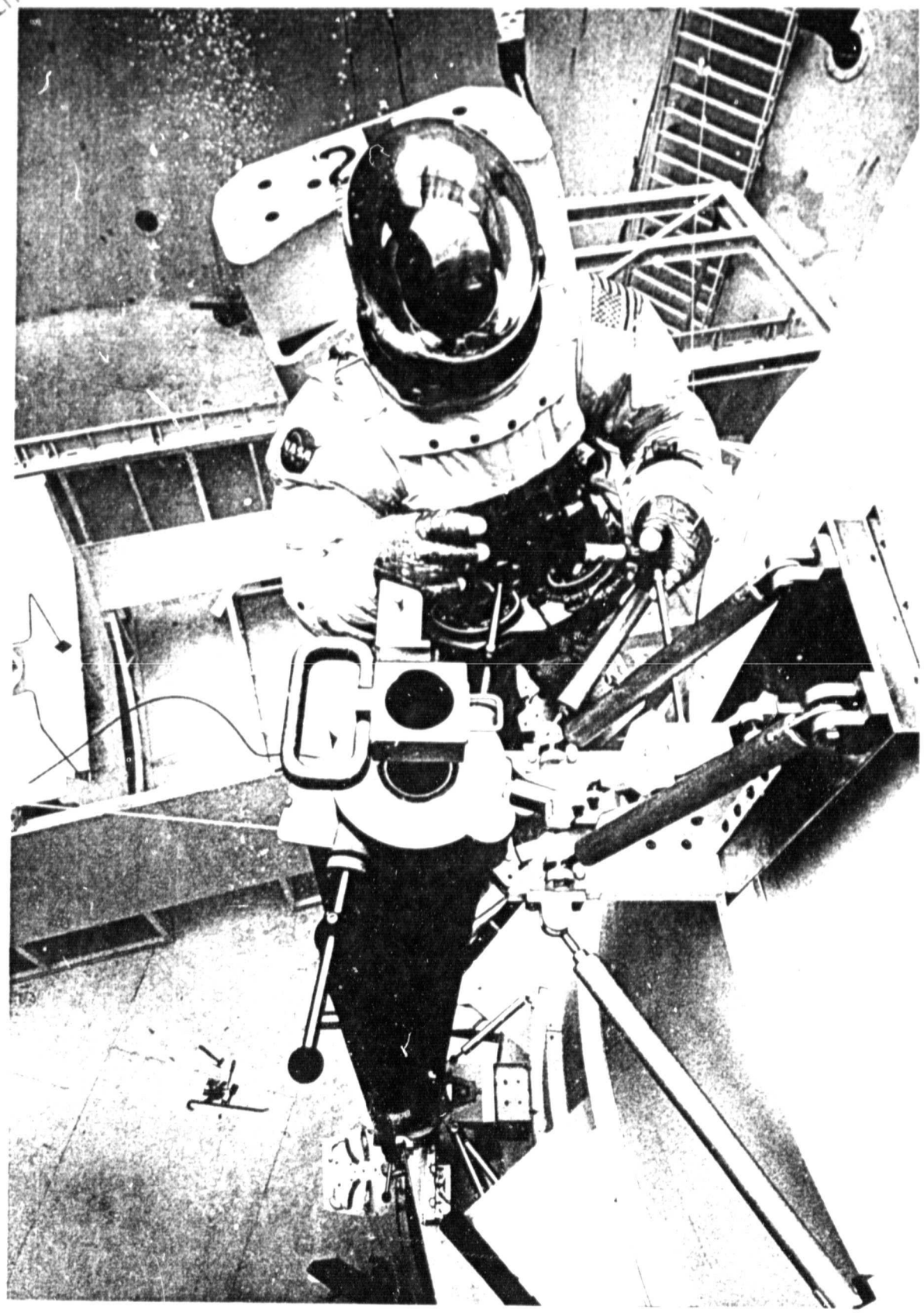

Figure 11: Solar Array Latch Release

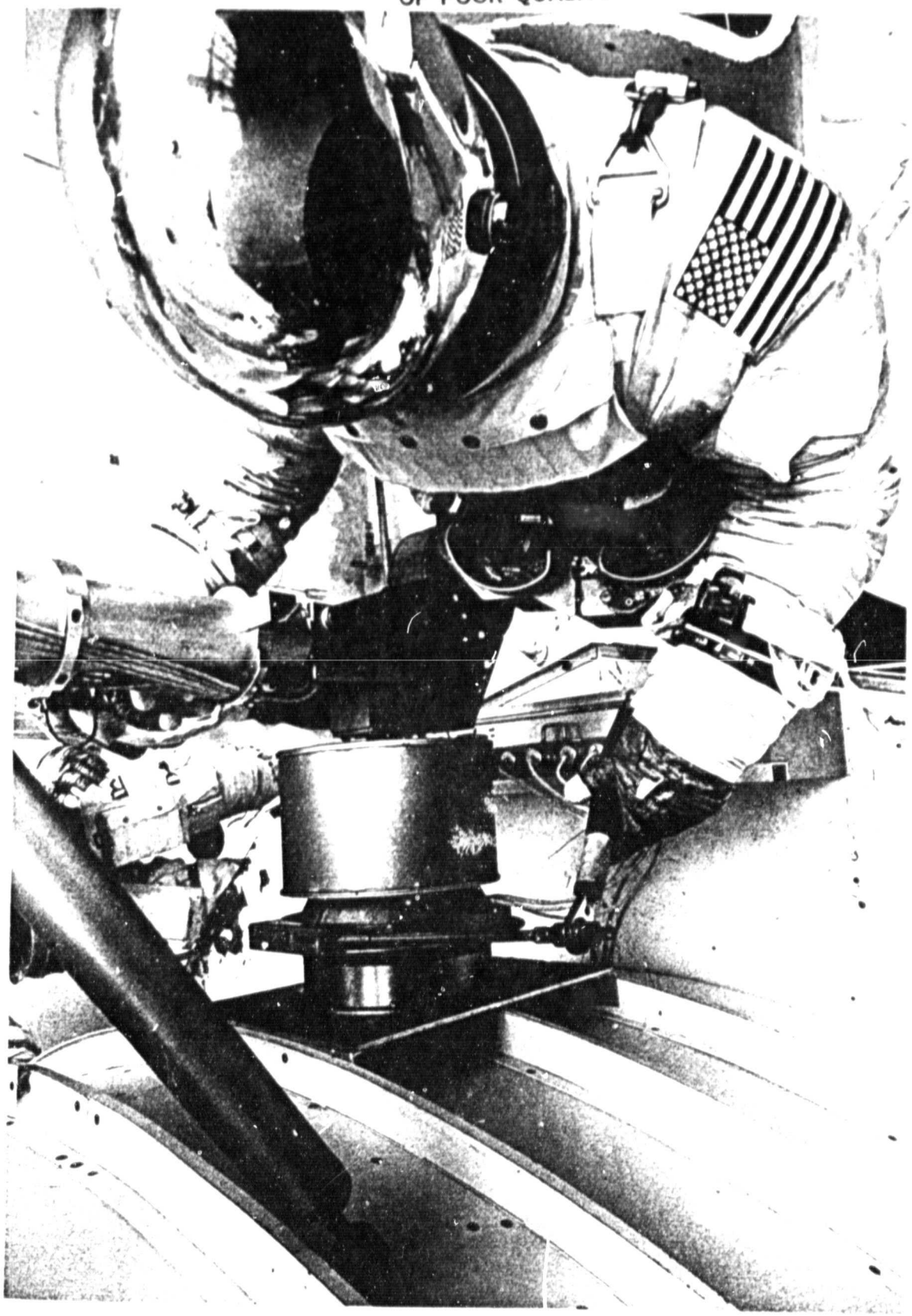

Figure 12: Solar Array Jettison Clamp Removal

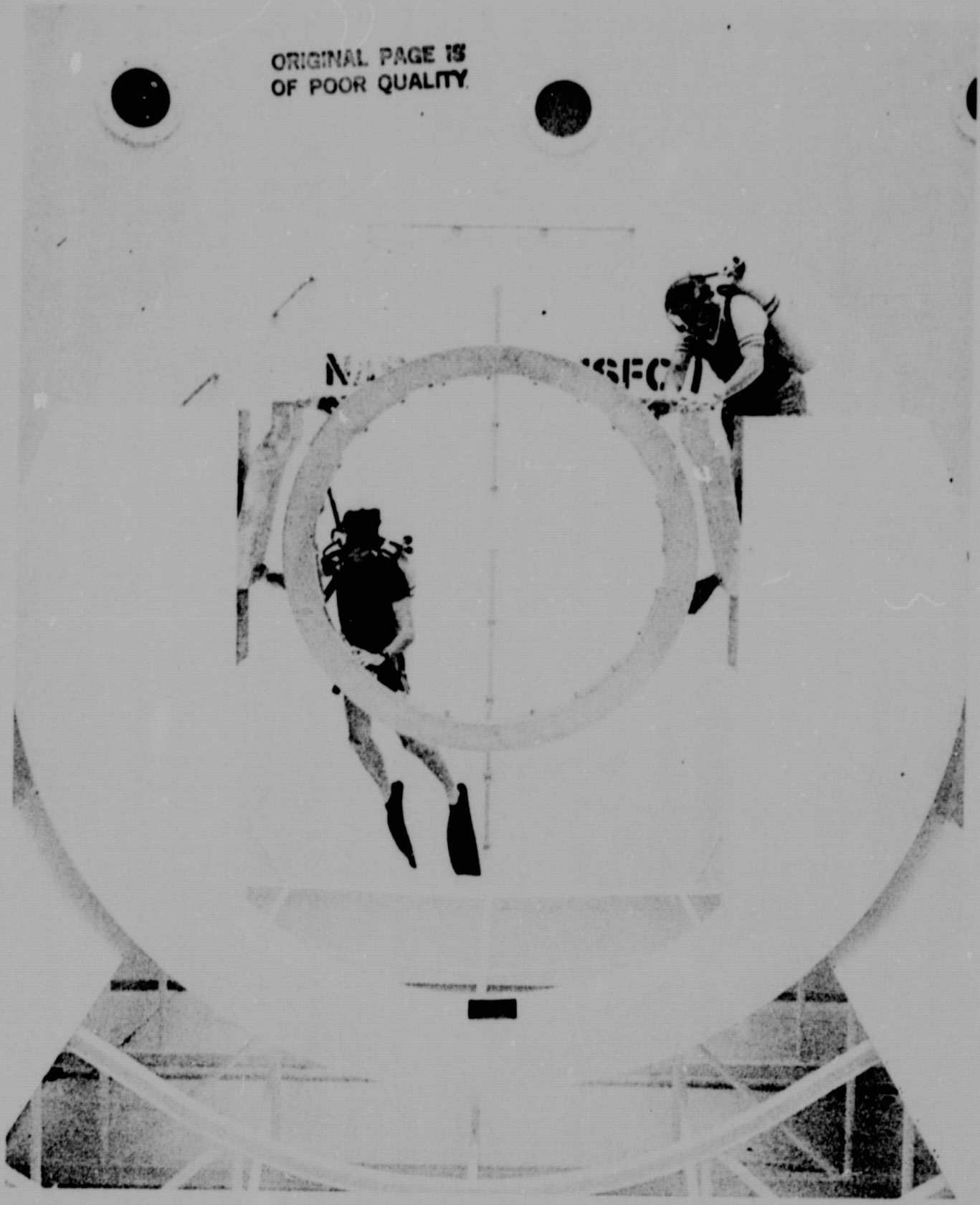

Figure 13: Flight Support System Cradle

Figure 14: FSS Berthing Ring

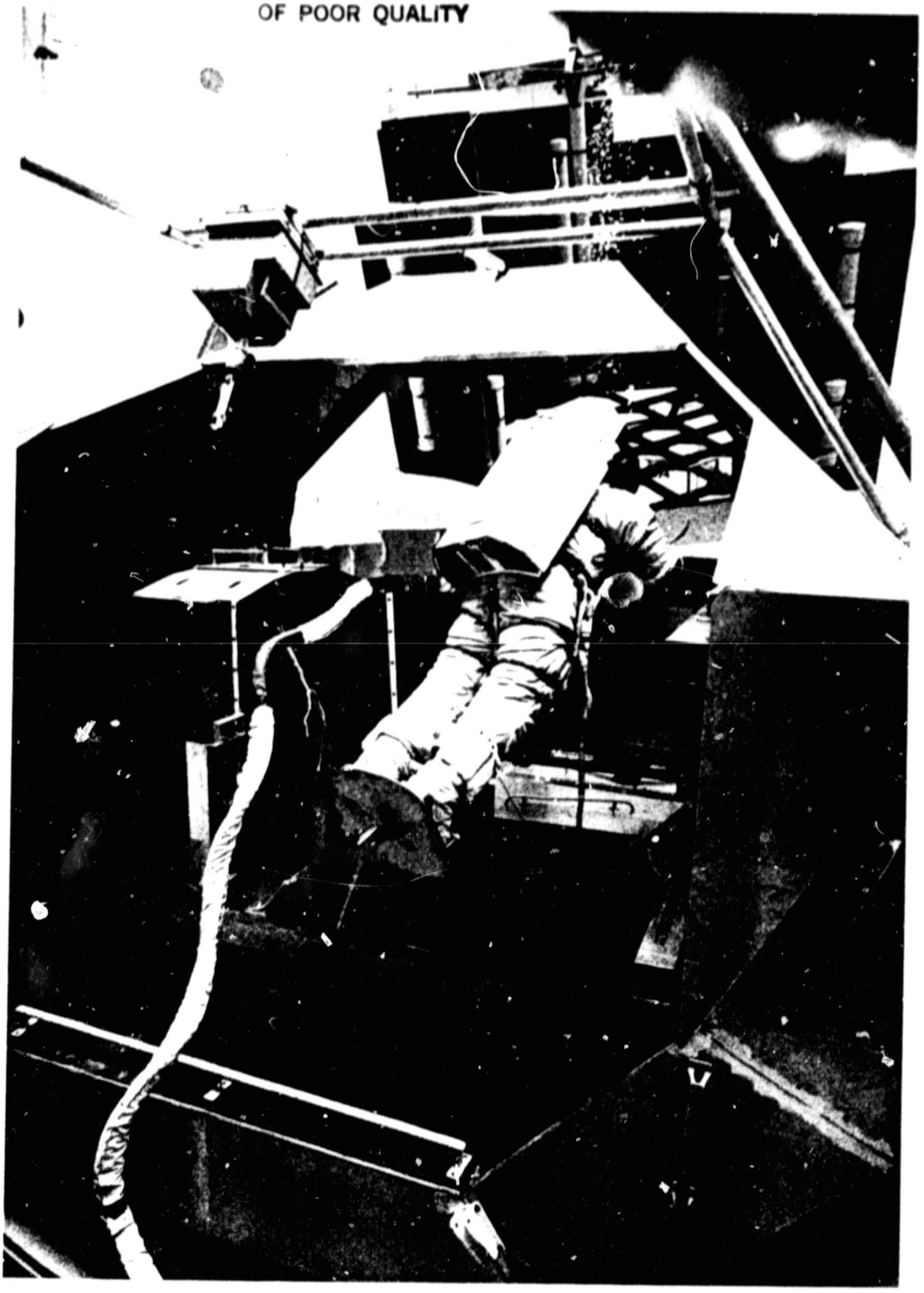

Figure 15: ORU Spares Carrier and Transfer Device

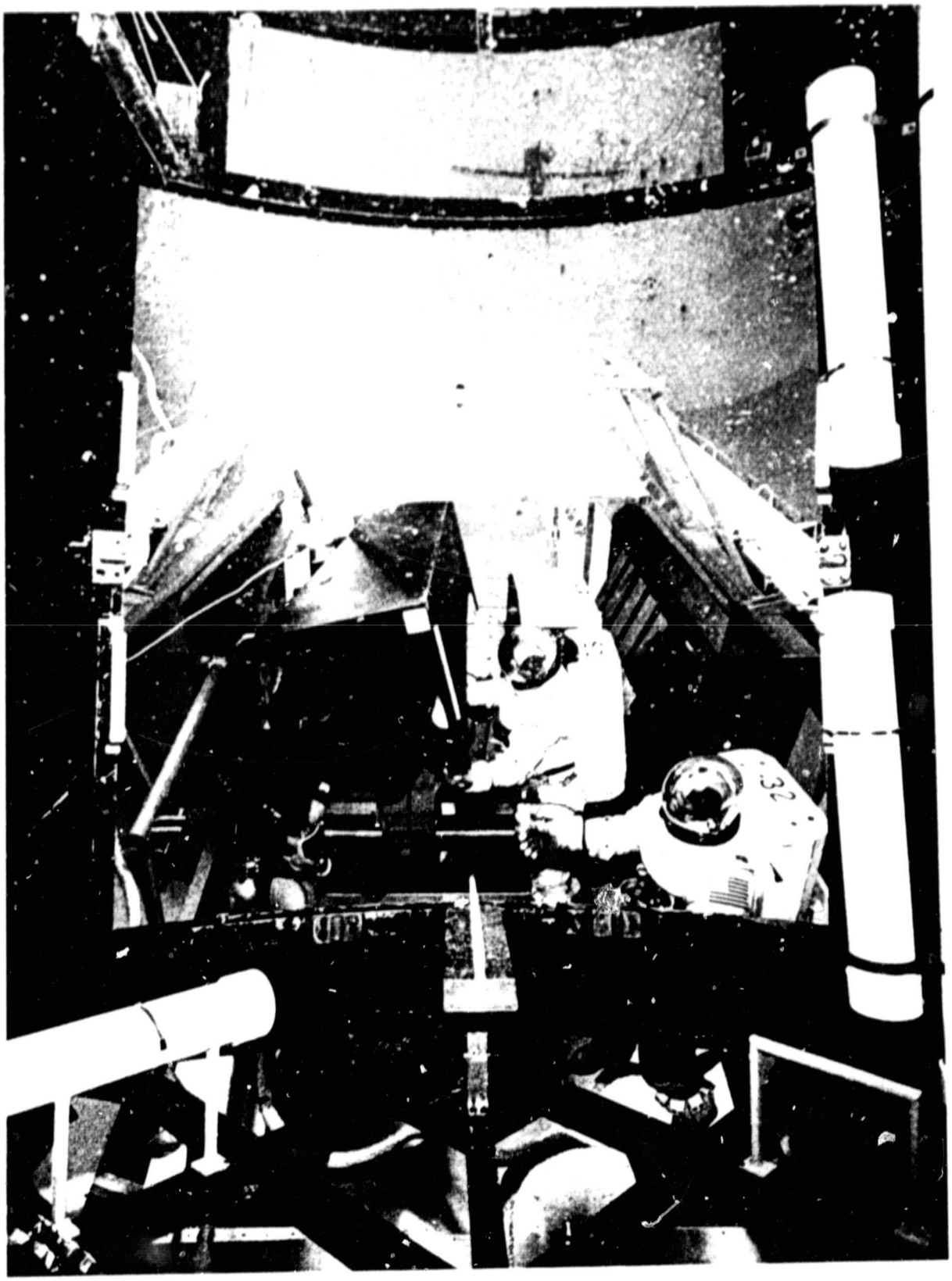

Figure 16: Spares Carrier - View from Space Telescope

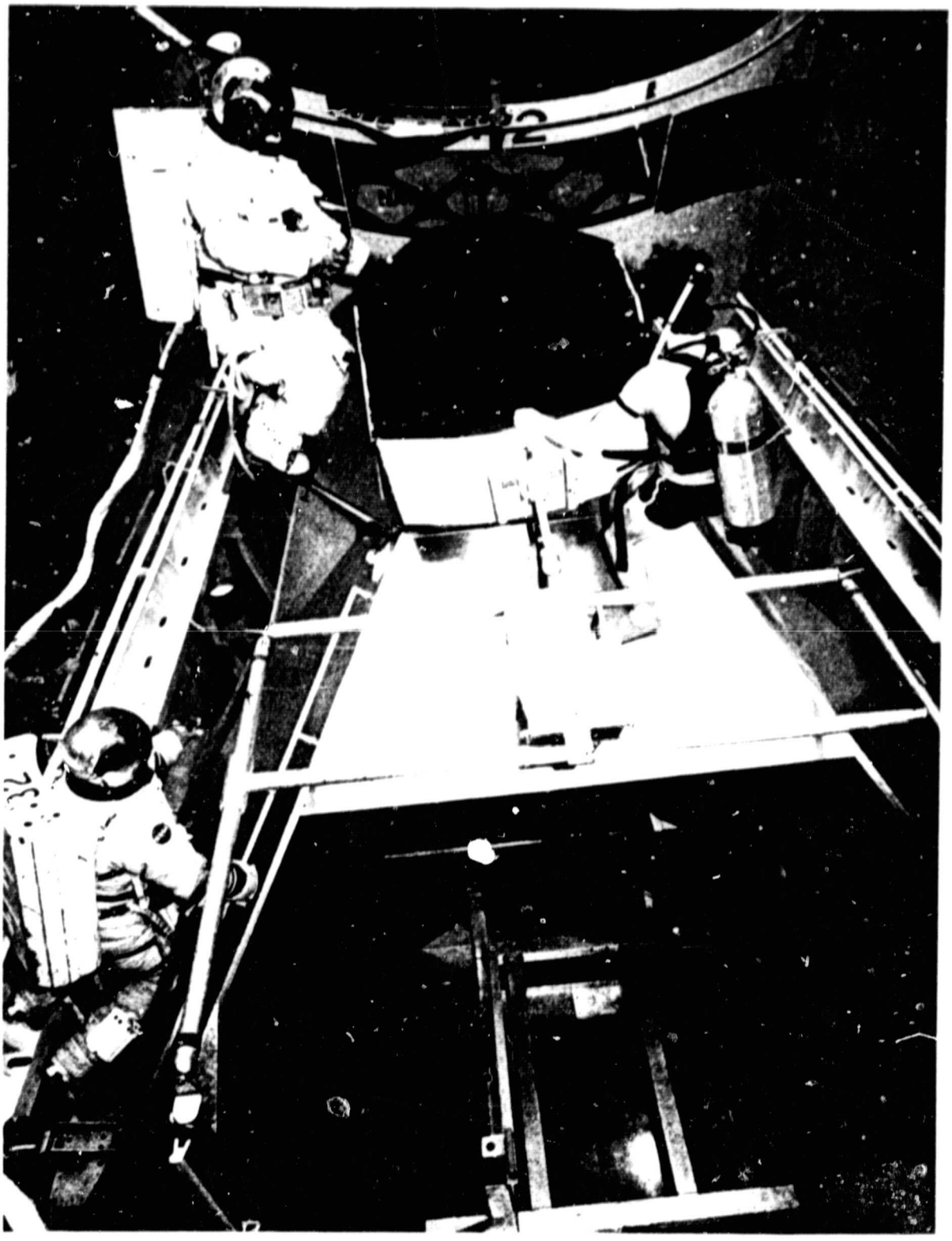

Figure 17: Transfer Device with Fine Guidance Sensor

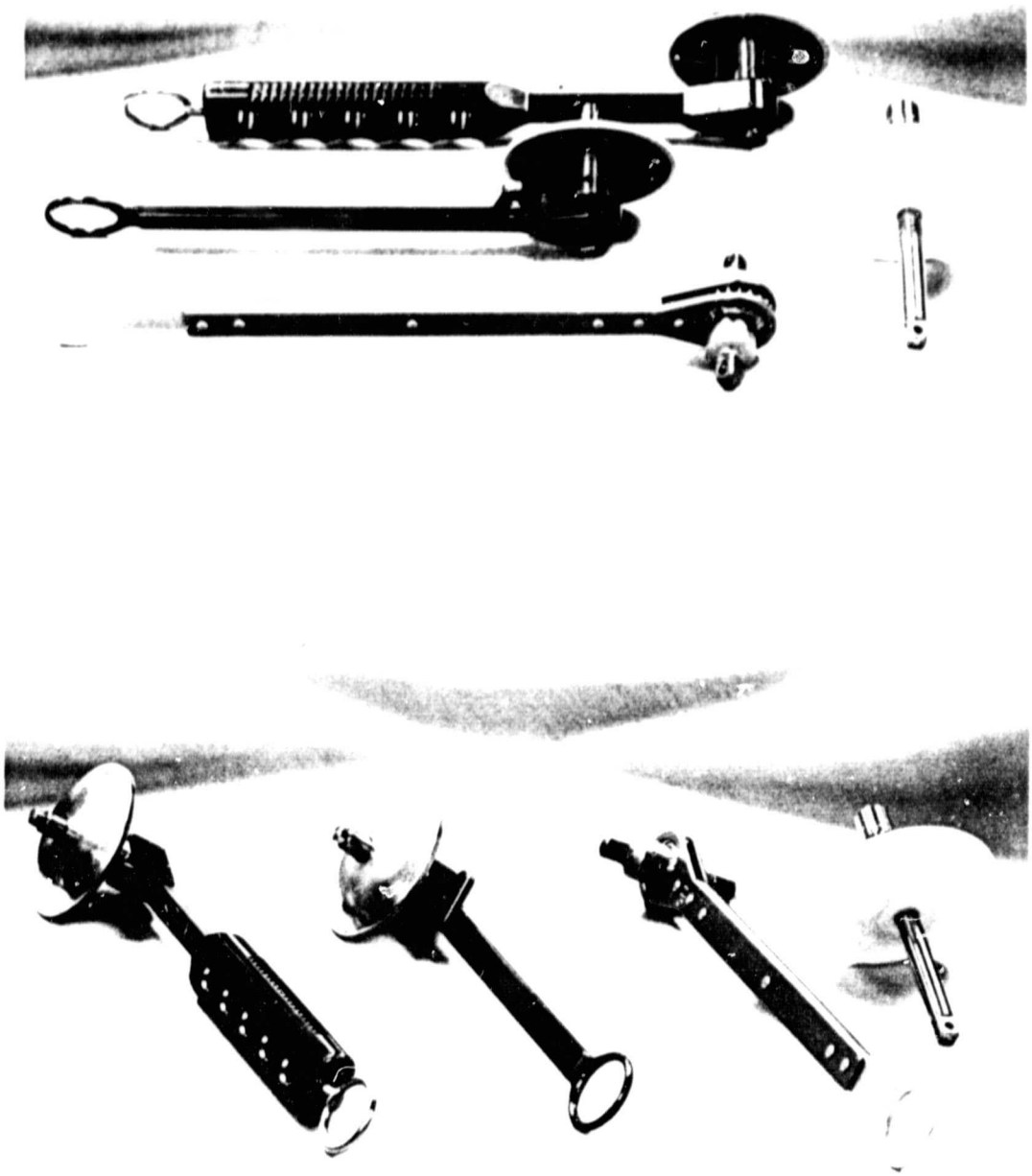

Figure 18: Space Telescope Servicing Tools - Development Models

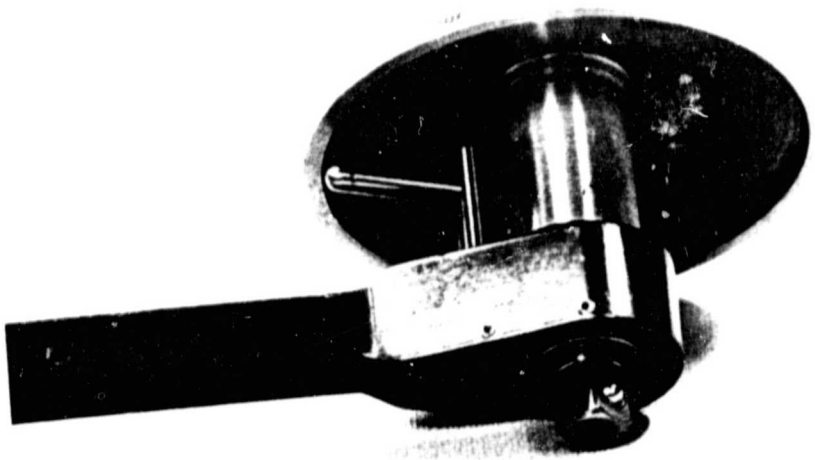

Figure 19: Space Telescope EVA Ratchet Wrench

3.2 SPACELAb

As a result of Modification No. 6 and 7, Essex used design and fabrication techniques developed for ST mockup development for production of Spacelab (SL) -1 and -2 pallet and experiment mockups.

3.2.1 Spacelab-1

Essex designed and fabricated the European Bridge Structure (EBS) mockup and the associated experiment hardware. This mockup is shown in Figure 20.

3.2.2 Spacelab-2

The three pallets and most of the experiment hardware were produced and assembled into the SL-2 configuration (Figure 21). Verification flight instrumentation (VFI) was also provided. Electrical connector mockups were provided on all experiments and VFI. The mockup is currently being used to develop flight electrical cable harnesses.

3.3 ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)

As a result of knowledge gained in performance of the basic ST contract and participation in the NBS tests, Essex developed a preliminary servicing plan for AXAF. This plan utilized but improved on existing ST servicing hardware and crew aids.

4.0 TEST OBSERVATIONS

Based on observations made during the Space Telescope NBS test series, it appears that the planned, unscheduled and contingency EVA tasks on Space Telescope are difficult for the crew members to perform. This is evidenced by the test experience which has shown that some of the planned and contingency tasks are very time consuming, are fatiguing to the crew, produce excessive glove wear during tool use, and require many foot restraint locations. The simulations have also demonstrated that the instruments can be jammed on the insertion rails, and are sometimes handled using instrument components not designed for crew interface. These problems are attributable somewhat to the size and mass of the instruments since they are large compared to the hardware handled by the crews during previous EVA's.

A second factor contributing to the problem is difficulty in complying with the existing EVA design standards. The design standards that apply to the Space Telescope servicing hardware include:

MSFC-STD 512, Man/System Design Criteria for Manned Orbiting Payloads
MSFC-STD 512A, Man/System Requirements for Weightless Environments
JSC-10615, Shuttle EVA Description and Design Criteria.

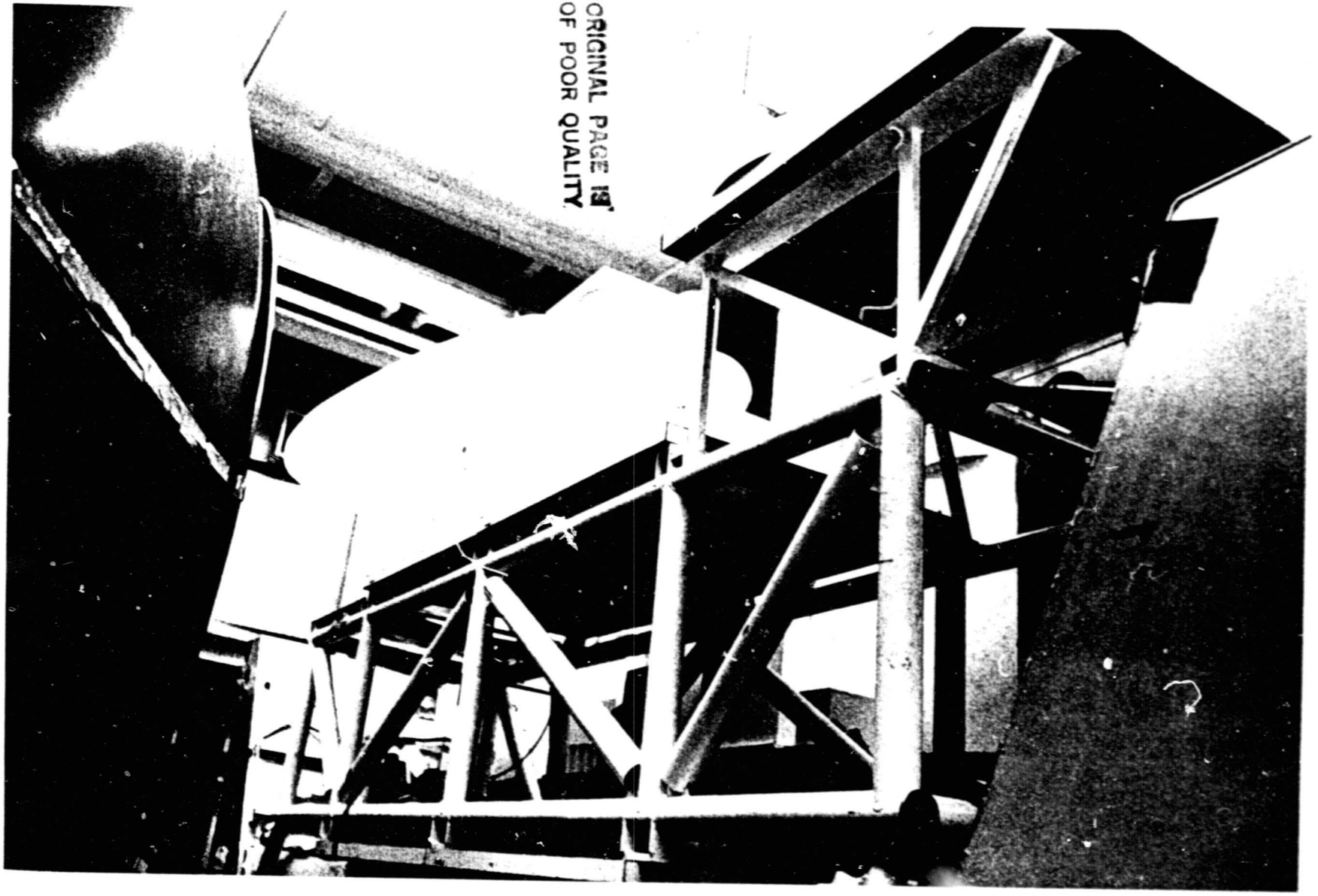

Figure 20: Spacelab 1 European Bridge Structure

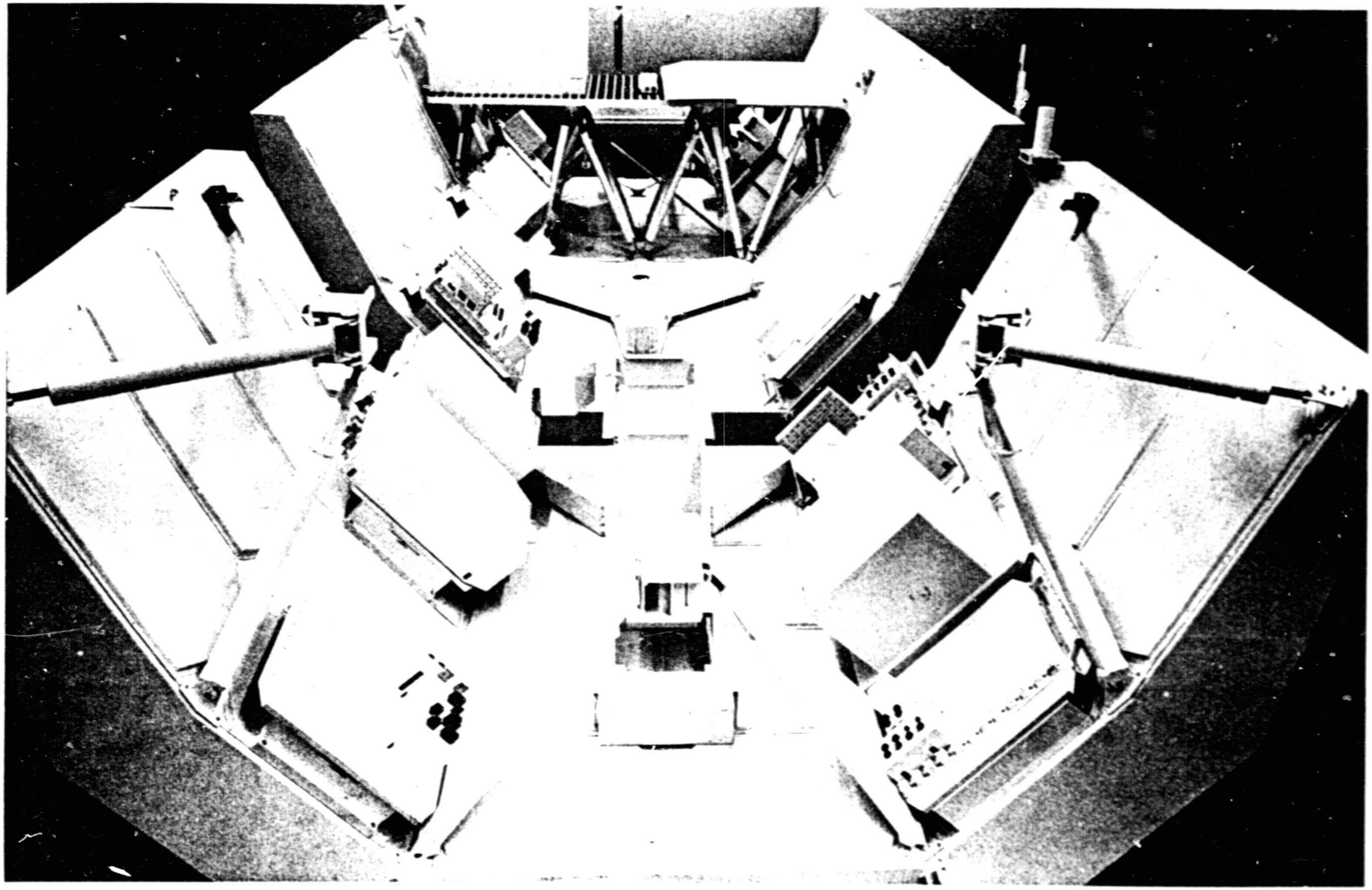

Figure 21: Spacelab 2 Pallets and Experiment Mockups

During a normal spacecraft development program, the program managers and designers would use these standards to identify human engineering design goals and specific design requirements. Table 2 lists some of the key design requirements that should be considered. As the spacecraft is developed and formal reviews are held, design standard violations should be identified per established RID procedures and resolved by equipment redesign, operational work arounds, or waivers.

Some of the difficulties of the planned and unscheduled EVA tasks could possibly have been prevented if these design requirements had been implemented prior to the NBS test series. For future Space Telescope neutral buoyancy tests it is recommended that the hardware and procedures be reviewed for compliance with the EVA design criteria and any discrepancies be resolved prior to testing. This would maximize the benefit of the test activity and reduce the time and cost of learning the same EVA lessons learned during past projects such as Skylab. It is also recommended that EVA crew interfaces be verified through one-G testing at MSFC and through early NBS testing prior to establishing baseline equipment designs that are difficult to change.

Table 2 - Applicable EVA Design Requirements

PARAGRAPH NO. MSFC 512	MSFC 512A	JSC 10615	DESIGN REQUIREMENT
3.2.2	4.4		Pip pins - Criticality of alignment is undesirable. Use as a launch lock is acceptable. Other fasteners are more desirable. No EVA use is recommended.
4.1.2			EVA tasks should bperformed by one crewman w/another EVA crewman observing & tending tethers.
4.1.3		3.3.9	Tasks that depend on dexterity and tactile feedback should be avoided.
4.1.4		3.3.9	Tool actuation force of 10 lbs is desired, 20 lbs maximum.
4.1.7		3.4	Exposed edges should have .06 in. radius or be guarded.
4.1.8			Portable foot restraints should be installed w/ one hand. Adjustments should be accomplished w/ one hand.
4.2.1			Premounted foot restraints will be used at all nominal worksites, contingency worksites may use crew installed restraints.
4.2.2			For replaceable modules all forward edges should be visible during alignment & attachment.
4.2.2			Hardware should require a push/pull force less than 35 lbs to install & remove.
4.2.2		3.3.10	Mechanical flag or status light shall be used to indicate removal or installation of a component.
4.2.2			The preferred screw type fastener is the internal hex head screw.